Assessment of Performance and Oil Recovery (%) in Existing Groundnut (*Arachis Hypogaea* L.) Accessions

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ABSTRACT

Groundnut cultivation in Bhutan is predominantly restricted to few farmers for its kernels whereby oil is usually not extracted. The rich agro-ecological diversity hosts a multitude of groundnut accessions that have not been studied so far. Based on geographical location, seed colour, seed shape or pattern, five local accessions, namely Chalipa badam, Bartshampa white badam, Yangbrangpa red badam, Yangbrangpa white and purple badam, and Nanongpa badam were identified in eastern Bhutan. A multi-location trial using RCB design was conducted across four agro-ecologically diverse locations namely; ARDC-Wengkhar, ARDSC-Lingmethang, ARDC-Samtenling, and ARDSC-Tsirang in April 2019. Days to 50 % flowering, plant height, number of pods per plant, thousand-seed weight, shelling %, yield, and oil recovery % were assessed. The yield performance of all five accessions was poor in the low/hot environment as compared to that in the mid/cool environment where all accessions, except Nanongpa badam which was marginally low yielding, gave satisfactory and similar yields. Correlation between the number of pods per plant and yield showed a high positive relationship (r = 0.75) whereas that between plant height and yield was negative (r=-0.57).

Keywords: *Groundnut; Accessions; Numbers of pods; Yield; Oil recovery %*

1. Introduction

Groundnut (*Arachis hypogaea* Linn.) is an important crop among oilseeds belonging to the family Leguminosae which is widely grown as an annual crop in the tropics and subtropics for its edible seeds and oil production around the world (Anjani & Khabiruddin, 2017; Ansah, Yaccub, & Rahman, 2017). Groundnut is often referred to as wonder nut, poor men's cashew nut (Madhusudhana, 2013; Ramapadmaja & Rao, 2019), peanut or gobber (Nasar, Qiang, & Alam, 2018), earthnut (Lawan, Ali, Abubakar, & Muhammad, 2015), monkey nut, and manila nut (Kokkiripati, Rai, Marker, & Veraja, 2015) owing to the development of fruits/pods below the ground (Akhtar et al., 2014; Yol, Furat, Upadhyaya, & Uzun, 2018; Zaman et al., 2011). Due to the rich digestible proteins, the crop is considered as 'king' of oil crops which is being produced from edible seeds and sometimes is referred to as Arachis oil and peanut oil (Aluyor, Aluyor, & Ozigagu, 2009; Konate et al., 2019; Madhusudhana, 2013; Ramapadmaja & Rao, 2019).

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Groundnut kernels contain 40-56 % edible oil, 20-30 % protein, 10-20 % carbohydrate, vitamins such as E, K and B (Kassa, Yeboah, & Bezabih, 2008; Savage G.P. & Keenan, 1994; Toomer, 2018), and dietary minerals such as niacin, calcium, magnesium, phosphorus, zinc, iron, riboflavin, thiamine, and potassium (Dean, Hendrix, Holbrook, & Sanders, 2009; Savage G.P. & Keenan, 1994). Groundnut oil is a rich source of plant sterol especially b-sitosterol, which is known to have anti-cancer properties and reduces cholesterol levels by 10-15% by inhibiting cholesterol absorption (Shasidhar et al., 2017). The cake obtained after oil extraction can be used in animal feed (Savage G.P. & Keenan, 1994) and it also improves soil fertility and productivity by fixing atmospheric nitrogen (Akhtar et al., 2014; Nautiyal et al., 2011). Globally, 37.1 million metric tons (MT) of groundnut production was reported from 26.4 million hectares with an average productivity of 1.4 MT per acre (Saravanan, Rajkala, & Alagukannan, 2018).

In Bhutan, groundnut is predominantly a minor crop grown by some farmers across the country. It may be grown for various purposes, such as for the sale of its kernels as a snack in the local market or for its above-ground biomass as nutritious fodder for animals. It is seldom grown for extracting its oil. After all, the availability of cheap imported refined vegetable oils of all kinds in the market leaves hardly any reason to go for local groundnut oil production which is not economical given the small-scale and scattered nature of the producers.

Although groundnut is hardly a crop of any economic importance in Bhutan, the rich diversity found within the crop is noteworthy due to the diverse agro-ecological environments. Genetically the crop may be the same but the specific local environment where it is grown can impart special traits over time giving each accession unique characteristics that contribute to their resilience and adaptation. In eastern Bhutan, five such local accessions of groundnut have been identified based on colour, the shape of the kernel, kernel size or colour patterns, and more importantly, based on where each accession is grown predominantly. Figure 1 shows the picture of each accession based on the above description.

Chalipa badam
Bartshampa white badam
Yabrangpa red badam
Yabrangpa white and purple badam
Nanongpa badam

Figure 1. Seed of groundnut accession studied.

To describe each accession briefly, Chalipa badam is typically found growing in Chali village, which features moderate pod beak and pod constriction with deep purplish-red colour seeds. Bartshampa white badam accession has off-white seed colour, slight pod beak, slight constriction of the pod, and moderate reticulation of the pod. In Yabrang village under Tashigang Dzongkhag, there are two groundnut accessions; one has dark red seed colour with moderate pod beak, slight pod constriction, and slight pod reticulation which is classified as Yabrangpa red badam, and the other has variegated striped purple and off-white seed patterns, slight pod beak, none pod constriction and slight reticulation of the pod (Yabrangpa white and purple). Nanongpa badam has a very prominent pod beak, a slight constriction of the pod, a prominent reticulation of the pod, and an elongated light tan seed.

Notwithstanding such diversity, there are hardly any studies done on groundnuts in Bhutan, leave alone the local accessions described above. Studying and documenting our local accessions/ germplasm is important as the first step towards any long-term development strategy of commodities.

This study was therefore done to assess the performance and adaptability of the five groundnut accessions in different agro-ecological environments of Bhutan.

2. Materials and methods

The experiment was conducted in four locations across the country under open field conditions namely; 1) Agriculture Research and Development Center (ARDC)-Wengkhar; 2) Agriculture Research and Development Sub-center (ARDSC)-Lingmethang; 3) ARDSC-Tsirang; 4) ARDC-Samtenling. The five groundnut accessions tested were: (T1 = Chalipa badam, T2 = Bartshampa white badam, T3 = Yangbrangpa red badam, T4 = Yangbranpa white and purple badam, T5 = Nanongpa badam). The multi-location trial was started in April 2019 using a randomized complete block design (RCBD) with three replications. Each experimental plot measured 4.5 m^2 with 0.5 m between treatments and 1 m alley between the blocks. The groundnut kernels were planted at the spacing of 30 cm between rows and 10 cm between plants. The agronomic practices inclusive of irrigation, weeding and earthing-up were followed as per the package of practices (PoP) of groundnut. A total of 10 plants (samples) from each plot were randomly tagged through a simple random sampling method for observation and assessment. The agronomic traits such as days to 50% flowering, plant height at maturity (cm), numbers of pods per plant, shelling percentage (%), yield (MT per acre), thousand-seed weight (g) and oil recovery percentage (%) were evaluated. The days to 50% flower formation were counted by days from sowing to date when 50% of the plants produced flowers in each plot. The heights of the 10 representative samples in each plot from ground level to the plants' growing tips were measured in centimeters to record plant height. The number of pods per plant (NPP) was recorded as the average number of pods from 15 randomly sampled plants. The pod yield was measured by weighing the dried pods from each plot and was recorded in kilograms per plot. Later, the measured yield was extrapolated to determine pod yield per acre of land by adopting the succeeding formula:

1. Yield (MT/ac) = [(Average yield of plot (kg) x 4000 m^2 x $_{MC\ (ad)}$/ (Plot size (m^2)] …(i)

To determine shelling percentage, pods of whole plots were shelled from seed and then converted into % by adopting the following formula (Raza et al., 2017; Jeyaramraja and Woldesenbet, 2014) below:

2. Shelling percentage (%) = (Total plot yield-yield after shelling/Total yield) x 100...…(ii)

At physiological maturity, 1000 kernels from tagged plants were assembled and their weights in grams measured.

The crude oil extraction was carried out only in ARDC-Wengkhar using a Japanese mini oil compressor (product model number d5 Rinka Ikuto, DK-119). Before extraction, the seeds were thoroughly sun-dried and peeled manually. A total of 0.5 kg of seeds from each plot was weighed for oil extraction. The determination of the oil recovery method was adopted from the study of Nkafamiya, Maina, Osemeahon, and Modibbo (2010) in which expelled oil was measured using a measuring cylinder and the unit was expressed in millilitres (ml).

The percentage (%) yield of oil was calculated using the equation (Pardeshi, 2019; Rodas & Cruz, 2017) below:

3. Oil recovery (%) = (Weight of oil (ml)/Weight of sample (g)) x 100……….... (iii)

The analysis of data was done using the statistical tool STAR and Stata software. The data from the four locations/sites were combined to examine location-accession interaction, main effects, and simple main effects. The Shapiro-Wilk test for normality of residuals and Bartlett's test for homogeneity of variance were carried out to check for violations of assumptions required for ANOVA. The Pearson correlation coefficient test was performed to determine the correlation matrix between the two variables. A probability level of $P < 0.05$ was considered significant.

3. Results and Discussions

3.1. Days to 50% flowering

Flowering traits in groundnut are indicative of the maturity period of genotype (Upadhyaya & Nigam, 1994; Upadhyaya, Reddy, Gowda, & Singh, 2006) and play a significant role in all seed crops (Kaba, Kumaga, & Ofori, 2014). The late-maturing groundnut genotypes generally took more days (> 30 days after planting) to reach 50% flowering (Oteng-Frimpong, Konlan, & Denwar, 2017; Poehlman & Sleper, 1995). The groundnut accessions that accumulate early flowers have the potential for developing early maturing and short-duration cultivars (Nigam & Aruna, 2008).

Combined analysis showed no significant site-accession interaction effect (P=0.40), no significant accession effect (P=0.90) but highly significant site effect (P=0.000).

Table 3. Mean number of days to 50% flowering of groundnut accessions across sites.

Location	Mean	Std. Err.	95% CI	
Wengkhar	48.60	0.77	47.02	50.18
Lingmethang	36.00	0.77	34.42	37.58
Tsirang	48.40	0.77	46.82	49.98
Samtenling	38.40	0.77	36.82	39.98

The accessions took about 11 days more to attain 50% flowering in the mid/cool environments (Wengkhar and Tsirang) than at low/hot environments (Lingmethang and Samtenling). The variation in 50% flowering days may be due to responses of each genotype to the growing environment (Oteng-Frimpong et al., 2017; Yol et al., 2018), genetic makeup (Ishag, 2000), and its taxonomic differences (Gupta, 2012) and growing temperature (Craufurd et al., 2000).

3.2. Plant height

The overall height of the accessions averaged across all four sites was 104.37±39.68 cm. The mean height of the accessions observed across the four sites showed that height from the Lingmethang trial was observed about 2.7 times more than that of Wengkhar or Tsirang and about 1.4 times of Samtenling as shown in Figure 2. This might be attributed due to the higher temperature prevalent there favouring rapid vegetative growth, but the same was not true at Samtenling where the height was only slightly taller than at Wengkhar/Tsirang, and one might suspect other reasons at play, such as over-fertilized plots.

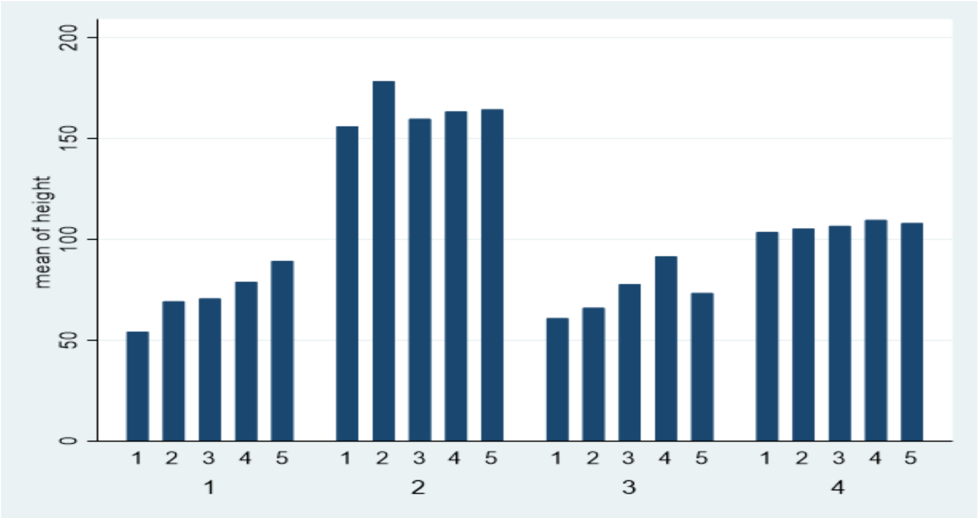


Figure 2. Mean height (cm) of accessions across the sites.

The correlation between height and yield was negatively related (-0.57) and it was highly significant (P=0.000). In general, it is a common fact that when plants partition a lot of energy towards vegetative growth, assimilation in the grains or fruits is reduced.

Overall, the accession Yabrangpa White and Purple badam exhibited the tallest height among other accessions (114.05 cm) and Chalipa badam with the shortest height (95.38 cm). Even though the combined analysis showed a significant effect of accession (P=0.000), this question cannot be answered straightforwardly since site-accession interaction was also significant (P=0.01). This variation in plant height could be attributed due to different growth rates of accessions (Raza et al., 2017), the response of accessions to the environment and the genetic makeup of the genotype (Kokkiripati et al., 2015).

3.3. Number of pods per plant

The number of pods per plant is one factor that determined the yield of the groundnut (Yol et al., 2018). The genotypes having a higher number of pods per plant provide an opportunity for improving seed yield in groundnut (Luz, Santos, & Filho, 2015). A scatter plot analysis of yield on the number of pods revealed there was an obvious positive linear relationship and this was also consistent with a high correlation coefficient of 0.75 (P=0.000).

3.4. Shelling recovery (%)

Shelling recovery percentage (%) is regarded as an index of the percentage of grains or seeds (Dapaah, 2014) and is a vital factor for selecting accessions in groundnut breeding (Anothai et al., 2008). Table 2 shows the shelling recovery percentage of the accessions across the four sites. The site-accession interaction was not significant (*P*=0.20), allowing for the main effect comparison. There was no significant difference amongst the accessions while the effect of location was significant (*P*=0.01).

Table 4. Mean shelling % of the accessions across the sites.

Treatment	**Experimental sites**				**Average shelling %**
	Wengkhar	**L/thang**	**Tsirang**	**S/ling**	
Chalipa badam	45.24	27.05	38.51	28.60	34.85
Bartshampa white badam	39.11	29.16	29.44	36.39	33.52
Yabrangpa red badam	32.22	28.42	31.06	33.06	31.19
Yabrangpa white and purple badam	38.53	28.77	34.53	27.17	32.25
Nanongpa badam	33.01	28.35	46.00	42.16	37.38
Average	37.62	28.35	35.91	33.48	33.84

The mean shelling recovery of the five accessions was highest for Wengkhar (37.6%) and lowest for Lingmethang (28.3%). The highest shelling recovery might be due to genotypic x environment interactions (Minimol, Datke, Deshmukh, & Satpute, 2001; Raza et al., 2017) and asserted due to the presence of calcium in the soil (Bucheyeki, 2008).

3.5. Thousand seed weight

The 1000 seed weight differed significantly between the various locations (*P*=0.000), with the S/ling mean being the highest and Lingmethang lowest as shown in Table 3. Within the accessions, except for a significant difference between Chalipa badam and Bartsampa badam and between Chalipa badam and Yangbrangpa white and purple badam, there were no significant differences between other pairs. This might be due to the yielding of larger seed size, production environment, and cultural practices (Yol et al., 2018).

Table 5. Mean thousand seed weight of the accessions across the locations.

Treatment	**Experimental sites**				**Average (g)**
	Wengkhar	**L/thang**	**Tsirang**	**S/ling**	
Chalipa badam	633.33	319.33	735.00	800.00	621.92
Bartshampa white badam	566.67	386.00	536.67	646.67	534.00
Yabrangpa red badam	583.33	340.33	696.67	736.67	589.25
Yabrangpa white and purple badam	516.67	273.67	631.67	673.33	523.83
Nanongpa badam	550.00	355.33	613.33	666.67	546.33
Average	**570.00**	**334.93**	**642.67**	**704.67**	**563.07**

3.6. Yield

Individual analysis of variances at each site revealed no significant difference in yield among the accessions. The accessions performed quite well at Tsirang followed by Wengkhar. The yield performance might have influenced due to cumulative performance of the genotype's response to environments, the genetic make-up of the specific accessions (Kokkiripati et al., 2015; Samaha, 2019), production environment, cultural practices (Yol et al., 2018) and air and soil temperature as groundnut flowers develop aerially and pods in the soil (Kumar, Singh, & Boote, 2012). However, the yield observed at S/ling was in particular very poor and that at L/thang was only slightly better but overall, it suggests that the accessions are not adapted to low/hot environments.

Table 6. Mean yield (MT/acre) of the five accessions over four sites with *P*-values and cv%.

Treatment	**Wengkhar**	**L/thang**	**Tsirang**	**S/ling**
Chalipa badam	1.837	0.667	3.500	0.050
Bartshampa white badam	1.837	0.783	4.367	0.037
Yabrangpa red badam	1.897	0.693	4.200	0.047
Yabrangpa white and purple badam	2.160	0.377	3.833	0.047
Nanongpa badam	1.643	0.947	2.867	0.037
P-value	0.15	0.29	0.18	0.49
CV (%)	11.48	42.92	17.17	25.97

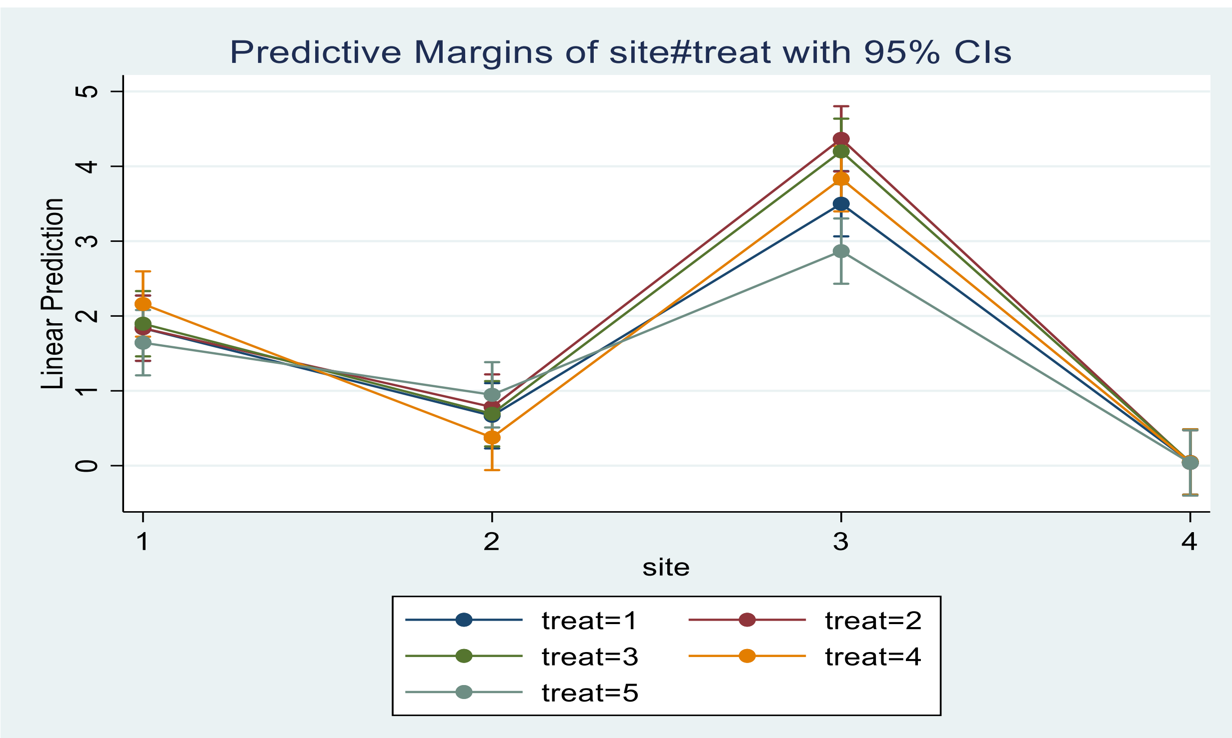


Figure 3. Predictive margins of sites.

Nonetheless, a combined analysis was performed which revealed that while site effect was highly significant (which was expected), accession effect was not and site-accession interaction was marginally significant (*P*=0.02), and this may be because all the accessions performed badly in low/hot environments while clearly showing good and marked within-accession differences at mid/cool environments as illustrated in Figure 3.

Given that the performance of the accessions is substantially poor at L/thang and S/ling, we may as well ignore them from the combined analysis so we can examine closely the performance and interaction effects at mid/cool environments where their promotion is most likely. Further, as Gomez and Gomez (1984) suggested, trial data from individual analysis of variance having cv% larger than 20% can be excluded from combined analysis.

Thus, combined analysis with L/thang and S/ling data excluded was carried out and the results showed significant effects of accession (*P*=0.03), while interaction effect disappeared as shown in Table 5.

Table 7. Combined ANOVA table.

Source	**Partial SS**	**df**	**MS**	**F**	**Prob>F**
Replication within site	1.0270267	4	0.256757	1.11	0.3849
Site	26.470412	1	26.47041	114.68	0.00000
Accession	3.0283866	4	0.757097	3.28	0.0383
site#accession	1.6838534	4	0.420963	1.82	0.1736
Residual	3.6932398	16	0.230827		
Total	**35.902919**	**29**	**1.238032**		

Since the site-accession interaction effect was not significant (*P*=0.17), we look at the main effects only and ignore the simple effects, i.e., we are not concerned with the differences among the accessions at respective sites even though it may be tempting as Figure 4 suggests. At best we can see that Yangbrangpa white and purple badam which yielded the highest at Wengkhar became the third-best performer at Tsirang, or Bartsampa white badam which was an average performer at Wengkhar taking the top spot at Tsirang. These are evidence of interaction occurring but as the test showed, it may be due to chance.

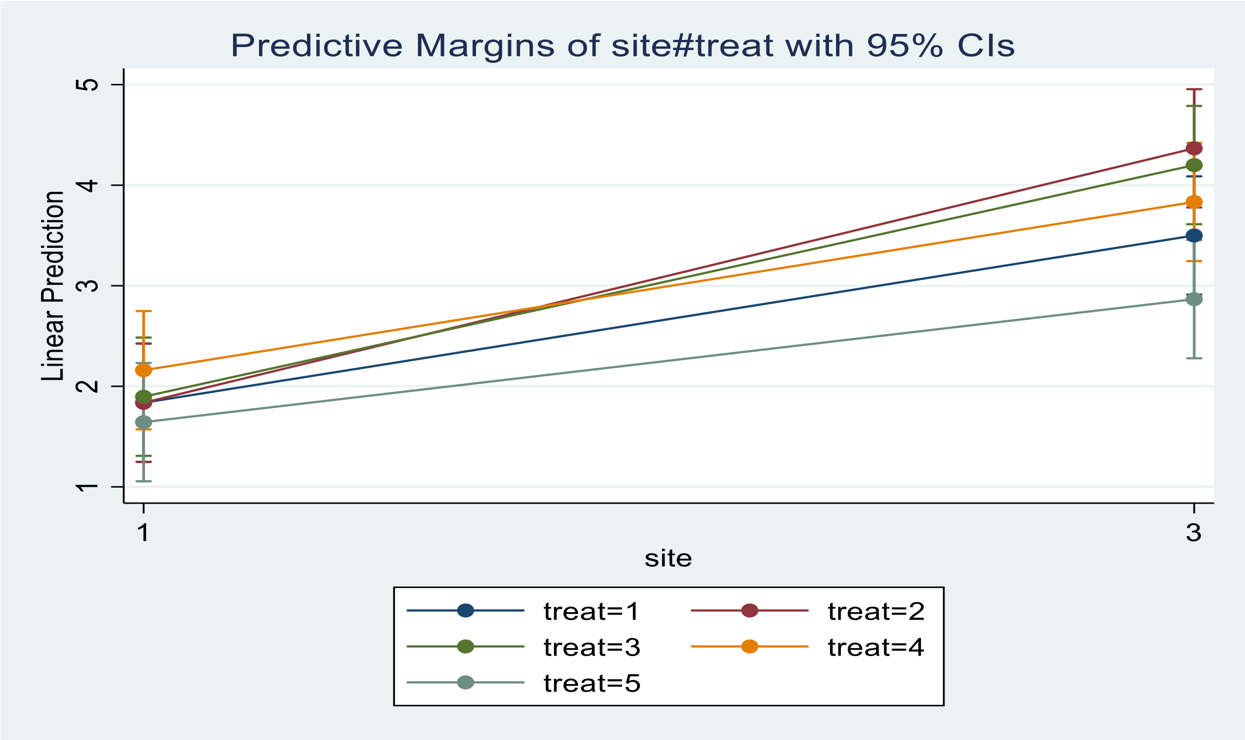


Figure 4. Predictive margins of sites.

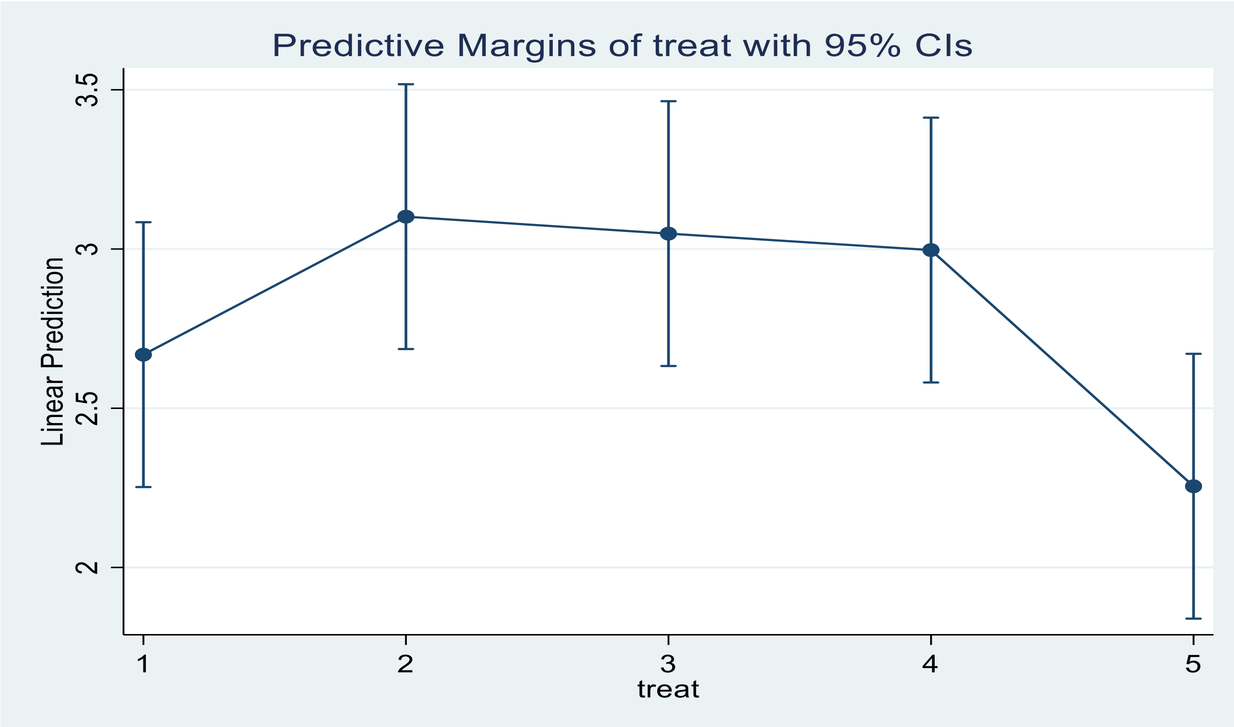


Figure 5. Predictive margins with 95% confidence intervals.

Coming back to the main effects of accession which was marginally significant (*P*=0.03), we looked at which pairwise differences were significant, using the Tukey-adjusted method. It was between Bartshampa badam p/w badam and Nanongpa badam (*P*=0.05), with all other pairs not significant as shown in Figure 5.

3.7. Oil recovery (%)

The mean groundnut oil recovery percent ranging from 18.6 to 30.73% signifies its suitability for commercial production (Anyasor et al., 2009). The analysis of variance showed no significant difference (*P*=0.53) in oil recovery percentage among the accessions. However, the genotype Chalipa badam revealed maximum oil recovery with 30.73% followed by Yangbrangpa white badam (25.33%) and lowest in Bartshampa white badam with 18.6% as shown in Table 6. The probability matrix showed that Chalipa badam has the potential to yield 553.29 litres of oil per acre followed by Yabrangpa white and purple badam (528.90 litre/acre), however, there are no statistically significant differences (*P*=0.53) between accessions. The highest oil content might be attributed to its agronomic traits, geographical locations (Kokkiripati et al., 2015), seed maturity, growing season, growth condition (Asibuo et al., 2008; Zahran & Tawfeuk, 2019), influence by climate status and temperature (Rodas & Cruz, 2017; Samaha, 2019). The result was similar to the standard groundnut oil content (32%) USDA 2008-2009, as cited in Akhtar et al. (2014).

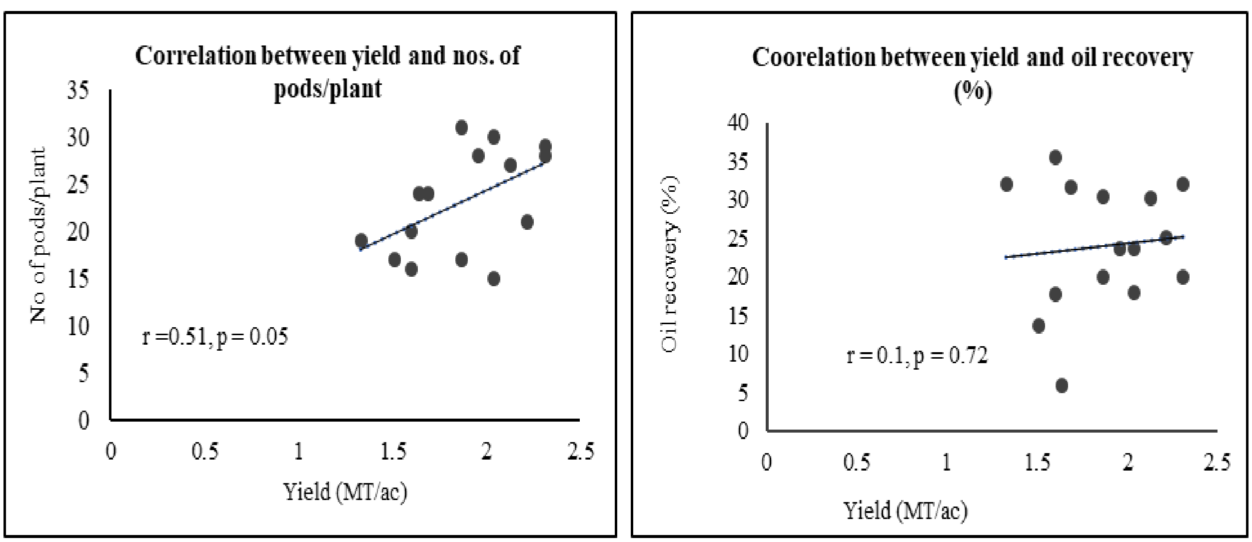
Table 8. Oil recovery (%) among five groundnut accessions.

Groundnut genotypes	Oil (ml/0.5 kg)	Oil content (l/ac)	Oil recovery (%)
Chalipa badam	153.67	553.29	30.73
Bartshampa white badam	93.00	342.00	18.60
Yangbrangpa white badam	126.67	504.35	25.33
Yangbrangpa white and purple badam	123.00	528.90	24.60
Nanongpa badam	102.67	329.17	20.53
***P*-value**	0.53	0.35	0.53
Standard error	36.23	133.57	7.25
SD	40.87	167.5	8.17
CV (%)	37.04	36.23	37.04
Mean	119.80	451.54	23.96

CV = Coefficient of variation, SD = Standard deviation, significant at P<0.05, means within columns followed by the different superscript letters indicates significance among the treatment.

3.8. Correlation matrix between yield, numbers of pods, and oil recovery (%)

The correlation coefficient between yield and oil recovery percentage showed a weak positive correlation (r=0.1) and was not statistically significant (*P*=0.72) as shown in Figure 6. It indicated that oil recovery percentage increases with an increase in groundnut yield. The correlation matrix between numbers of pods per plant and yield showed statistically significant (*P*=0.05) with a moderate positive correlation (r=0.51) as revealed in Figure 6. Similarly, a study by Shah et al. (1993) reported that yield was positively correlated with the number of pods per plant.



4.Figure 6. Correlation matrix of studied parameters in the native groundnut accessions.

Based on this one season cropping trial, in general, the groundnut accessions attained 50% flowering earlier or grew taller in the low/hot environments represented by Lingmethang-Samtenling type of environments than in mid/cool environments represented by Wengkhag-Tsirang type of environments. However, in terms of yield performance which is perhaps the main agronomic trait of interest all the five accessions performed poorly in the low/hot as compared to mid/cool environments. Closer examination within the mid/cool environment showed that all accessions, except Nanongpa badam which was marginally low yielding, gave similar yields. The oil recovery assessment, which was done only for the Wengkhar site showed promising results, especially for Chalipa badam.

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References

Akhtar, S., Khalid, N., Ahmed, I., Shahzad, A., & Suleria, H. A. (2014). Physicochemical characteristics, functional properties, and nutritional benefits of peanut oil: a review. *Crit Rev Food Sci Nutr, 54*(12), 1562-1575. doi:10.1080/10408398.2011.644353

Aluyor, E., Aluyor, P., & Ozigagu, C. E. (2009). Effect of refining on the quality and composition of groundnut oil. *African Journal of Food Science, 3*, 201-205.

Anjani & Khabiruddin, M. (2017). Extraction and characterization of crude and refined groundnut (*Arachis hypogaea* Linn) oil. *International Journal of Chemical Studies, 5*(6), 2031-2033.

Anothai, J., Patanothai, A., Jogloy, S., Pannangpetch, K., Boote, K. J., & Hoogenboom, G. (2008). A sequential approach for determining the cultivar coefficients of peanut lines using end-of-season data of crop performance trials. *Field Crops Research, 108*(2), 169-178.

Ansah, T., Yaccub, Z. I., & Rahman, N. A. (2017). Growth performance and hematology of Djallonké rams fed haulms of four varieties of groundnut (*Arachis hypogaea* L.). *Animal Nutrition, 3*(4), 406-410. doi:10.1016/j.aninu.2017.08.006

Anyasor, G. N., Ogunwenmo, K. O., Oyelana, O. A., Ajayi, D., & Dangana, J. (2009). Chemical analyses of groundnut (*Arachis hypogaea*) oil. *Pakistan Journal of Nutrition, 8*(3), 269-272.

Asibuo, J., Akromah, R., Adu-Dapaah, H., Safo-Kantanka, O., & Development. (2008). Evaluation of nutritional quality of groundnut (*Arachis hypogaea* L.) from Ghana. *African Journal of Food, Agriculture, Nutrition, 8*(2), 133-150.

Bucheyeki, T. L., Shenkalwa, E.M., Mapunda, T.X & Matata, L.W (2008). On-farm evaluation of promising groundnut varieties for adaptation and adoption in Tanzania. *African Journal for Agriculture Research, 3*(8), 531-536.

Craufurd, P. Q., Wheeler, T. R., Ellis, R. H., Summerfield, R. J., & Prasad, V. P. V. (2000). Escape and tolerance to high temperature at flowering in groundnut (*Arachis hypogaea* L.). *The Journal of Agricultural Science, 135*(4), 371-378.

Dapaah, H. K., Mohammed, I & Awuah, R.T. (2014). Growth and yield performance of groundnuts (*Arachis hypogaea* L.) in response to plant density. *International Journal of Plant & Soil Science, 3*(9), 1069-1082.

Dean, L., Hendrix, K. W., Holbrook, C., & Sanders, T. (2009). Content of Some Nutrients in the Core of the Core of the Peanut Germplasm Collection. *Peanut Science, 36*(2), 104-120.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research* (2 ed.). New York: John Wiley Sons & inc.

Gupta, S. (2012). *Technological Innovations in Major World Oil Crops, Volume 1*. New York: Springer.

Ishag, H. M. (2000). Phenotypic and yield responses of irrigated groundnut cultivars in a hot environment. *J Experimental Agriculture, 36*(3), 303-312.

Kaba, J. S., Kumaga, F. K., & Ofori, K. (2014). Effect of flower production and time of flowering on pod yield for peanut (*Arachis hypogaea* L) genotypes. *Journal of Agriculture Veterinary Science, 7*(4), 2319-2372.

Kassa, M. T., Yeboah, S. O., & Bezabih, M. (2008). Profiling peanut (*Arachis hypogea* L.) accessions and cultivars for oleic acid and yield in Botswana. *Euphytica, 167*(3), 293-301.

Kokkiripati, C. R., Rai, P. C., Marker, S., & Veraja, P. (2015). Study on the performance of Groundnut (*Arachis hypogea* L.) genotypes for seed yield and quality traits. *Annals of West University of Timisoara, 18*(2), 139-144.

Konate, M., Sanou, J., Miningou, A., Okello, D. K., Desmae, H., Janila, P., & Mumm, R. H. (2019). Past, Present and Future Perspectives on Groundnut Breeding in Burkina Faso. *Agronomy, 10*(5), 704.

Kumar, U., Singh, P., & Boote, K. J. (2012). Effect of Climate Change Factors on Processes of Crop Growth and Development and Yield of Groundnut (*Arachis hypogaea* L.). *Advances in Agronomy, 116*, 41-69.

Lawan, I., Ali, M. A., Abubakar, M. S., & Muhammad, A. I. (2015). An overview of Groundnut Oil Extraction Technologies. In *Proceedings of Second International Interdisciplinary Conference on Global Initiatives for Integrated Development* (pp. 2-5). Nigeria: Chukwuemeka Odumegwu University.

Luz, L. N., Santos, R. C., & Filho, P. A. M. (2015). Correlations and path analysis of peanut traits associated with the peg. *Crop Breeding and Applied Biotechnology, 11*(1), 88-95.

Madhusudhana, B. (2013). A Survey on Area, Production and Productivity of Groundnut crop in India. *IOSR Journal of Economics and Finance, 1*(3), 01-07.

Minimol, J. S., Datke, S. B., Deshmukh, S. N., & Satpute, G. N. (2001). Genotype×environment interaction in groundnut (*Arachis hypogaen* Linn.). *Annals of Plant Physiology, 14*(1), 74-79.

Nasar, J., Qiang, G., & Alam, A. (2018). Groundnut response to Boron and Molybdenum. *Journal of Science Frontier Research: D Agriculture Veterinary, 18*(1), 16-22.

Nautiyal, P. C., Zala, P. V., Tomar, R. K., Sodayadiya, P., & Tavethia, B. (2011). Evaluation of water use efficiency newly developed varieties of groundnut in on-farm trials in two different rainfall areas in Gujarat, India. *Journal of SAT Agricultural Research, 9*, 1-6.

Nigam, S., & Aruna, R. (2008). Improving breeding efficiency for early maturity in peanut. *J Plant breeding reviews, 30*, 295-322.

Nkafamiya, I., Maina, H., Osemeahon, S., & Modibbo, U. (2010). Percentage oil yield and physiochemical properties of different groundnut species (*Arachis hypogaea*). *African Journal of Food Science, 4*(7), 418-421.

Oteng-Frimpong, R., Konlan, S. P., & Denwar, N. N. (2017). Evaluation of selected groundnut (*Arachis hypogaea* L.) lines for yield and haulm nutritive quality traits. *International Journal of Agronomy, 2017*. doi:https://doi.org/10.1155/2017/7479309

Pardeshi, S. (2019). Assessment of Proximate Composition of Groundnut Seeds and Characterization of their Extracted oils from Different Varieties Grown in India. *International Research Journal of Engineering and Technology, 06*(08), 854-862.

Poehlman, J. M., & Sleper, D. A. (1995). *Breeding Field Crops* (4 ed.). Ames: Iowa State University Press.

Ramapadmaja, & Rao, T. M. (2019). Impact of Technology on Groundnut Production of the Chittoor District. *International Journal of Recent Technology and Engineering, 8*(IS4), 933-938.

Raza, A., Khan, Z. H., Khan, K., Anjum, M. M., Ali, N., Iqbal, M. O., & Usman, H. (2017). Evaluation of Groundnut Varieties for the Agro-Ecological Zone of Malak and Division. *International Journal of Environmental Sciences & Natural Resources*, *5*(5), 93-96.

Rodas, M. P. C., & Cruz, S. M. (2017). Characterization of seed oil from *Arachis hypogaea* cultivated in Guatemala for applications in lips gloss and skin cream. *International Journal of Phytocosmetics and Natural Ingredients*, *4*(1), 6-6.

Samaha, M. G., Ahmed, M.A & Hameid, A.R E (2019). Assessment of growth and productivity of five peanut cultivars and genetic diversity using RAPD markers. *Bulletin of the National Research Center*, *43*(1), 1-11.

Saravanan, M., Rajkala, A., & Alagukannan, G. (2018). Assessment of Drought Tolerant and High Yielding Groundnut Varieties in Ariyalur District, India. *International Journal of Current Microbiology Applied Sciences*, *7*(5), 3492-3499.

Savage G.P., & Keenan, J. I. (1994). The composition and nutritive value of groundnut kernels. In *The Groundnut Crop. World Crop Series* (pp. 173-213). Dordrecht: Springer.

Shasidhar, Y., Vishwakarma, M. K., Pandey, M. K., Janila, P., Variath, M. T., Manohar, S. S., . . . Varshney, R. K. (2017). Molecular mapping of oil content and fatty acids using dense genetic maps in groundnut (*Arachis hypogaea* L.). *J Frontiers in plant science, 8*, 794.

Toomer, O. T. (2018). Nutritional chemistry of the peanut (*Arachis hypogaea*). *Crit Rev Food Sci Nutr, 58*(17), 3042-3053. doi:10.1080/10408398.2017.1339015

Upadhyaya, H. D., & Nigam, S. N. (1994). Inheritance of two components of early maturity in groundnut (*Arachis hypogaea* L.). *Euphytica*, *78*(1), 59-67.

Upadhyaya, H. D., Reddy, L. J., Gowda, C. L. L., & Singh, S. (2006). Identification of diverse groundnut germplasm: Sources of early maturity in a core collection. *Field Crops Research*, *97*(2), 261-271. doi:https://doi.org/10.1016/j.fcr.2005.10.010

Yol, E., Furat, S., Upadhyaya, H. D., & Uzun, B. (2018). Characterization of groundnut (*Arachis hypogaea* L.) collection using quantitative and qualitative traits in the Mediterranean Basin. *Journal of Integrative Agriculture*, *17*(1), 63-75. doi:https://doi.org/10.1016/S2095-3119(17)61675-7

Zahran, H. A., & Tawfeuk, H. Z. (2019). Physicochemical properties of new peanut (Arachis hypogaea L.) varieties. *Oil seeds and fats crops and lipids, 26 (2019),* 19. doi:https://doi.org/10.1051/ocl/2019018

Zaman, M., Tuhina-Khatun, M., Ullah, M., Moniruzzamn, M., & Alam, K. (2011). Genetic variability and path analysis of groundnut (*Arachis hypogaea* L.). *The Agriculturists*, *9*(1-2), 29-36.